

THE CLAIMS

1. A composite comprised of at least two materials that exhibits a threshold strength in which

the materials are strongly bonded together;

residual, compressive stresses exist in only one of the materials;

the material containing the compressive stresses stops cracks extending from the other material(s) at an applied tensile stress less than the threshold strength;

each material has a different chemical composition relative to the other(s);

the material(s) that do(es) not contain the compressive stresses possess(es) the largest volume fraction in the composite;

the material containing compressive stresses separates and exists between the regions of the material(s) that do(es) not contain compressive stresses;

the dimension of materials that do not contain compressive stresses, measured perpendicular to the interface between the materials, is smaller than 1000 microns;

the thickness of the regions that contain the compressive stresses is between 1 times and 0.001 times the dimension of the material(s) that do(es) not contain the compressive stresses, as measured from the interface between the two materials; and

the compressive stress is greater than 100 MPa.

2. A composite as in claim 1, in which layers of one material are separated by alternating layers of one or more other materials; and in which all sets of layers are bonded together; and in which one of the alternating materials contains biaxial, residual, compressive stresses; and in which, at applied tensile stresses less than a threshold value, cracks that extend into the compressive layers are stopped and cannot cause catastrophic failure.
3. A composite as in claim 1, in which prismatic cylinders of one or more materials are separated and bonded to another material that contains residual compressive stresses; and in which, at applied tensile stresses less than a threshold value, cracks that attempt to propagate from the prismatic cylinders into the compressive layers are stopped and cannot cause catastrophic failure.

4. A composite as in claim 1, in which polyhedra of one or more materials are separated and bonded to another material that contains residual compressive stresses; and in which, at applied tensile stresses less than a threshold value, cracks that attempt to propagate from the polyhedra into the compressive layers that surround the polyhedra are stopped and cannot cause catastrophic failure.
5. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite.
6. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by a volume expansion of one of the materials that undergoes a crystallographic phase transformation during cooling.
7. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise when two materials react together to form a third material, and this reaction is accompanied by an increase in molar volume which is constrained by a fourth material that does not take part in the reaction.
8. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise when two materials react together to form a third material; and in which this reaction is accompanied by an increase in molar volume which is constrained by a fourth material that does not take part in the reaction; and in which the two materials that react together are silica (SiO_2) and alumina (Al_2O_3), which form mullite ($3 \text{ Al}_2\text{O}_3 : 2 \text{ SiO}_2$), the third material; and in which this reaction produces a molar volume increase which, when constrained by a fourth material, such as but not limited to alumina (Al_2O_3), will produce a compressive stress.
9. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite; and in which the materials are chosen from a list that includes at least two materials that do not react together to form a third material, but have differential thermal contraction coefficients such that compressive stresses would arise in one of the materials during cooling from a processing temperature, this list including, but not limited to, alumina (Al_2O_3), zirconia (ZrO_2), mullite ($3 \text{ Al}_2\text{O}_3 : 2 \text{ SiO}_2$), silicon nitride (Si_3N_4), silicon carbide (SiC), and titania (TiO_2).
10. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite; and in which the materials are chosen from a list that includes at least two materials that do not react together to

form a third material, but have differential thermal contraction coefficients such that compressive stresses would arise in one of the materials during cooling from a processing temperature, this list including, but not limited to, alumina (Al_2O_3), zirconia (ZrO_2), mullite ($3 \text{ Al}_2\text{O}_3 : 2 \text{ SiO}_2$), silicon nitride (Si_3N_4), silicon carbide (SiC), and titania (TiO_2); and in which the material(s) that do(es) not contain the compressive stresses do(es) contain another material that would impart an additional property important to mechanical strength and thus optimize factors that affect threshold strength that include, but are not limited to, controlling grain growth, changing the coefficient of thermal contraction, and changing the elastic modulus.

11. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite; and in which the materials are chosen from a list that includes at least two materials that do not react together to form a third material, but have differential thermal contraction coefficients such that compressive stresses would arise in one of the materials during cooling from a processing temperature, this list including, but not limited to, alumina (Al_2O_3), zirconia (ZrO_2), mullite ($3 \text{ Al}_2\text{O}_3 : 2 \text{ SiO}_2$), silicon nitride (Si_3N_4), silicon carbide (SiC), and titania (TiO_2); and in which the material that contains the compressive stresses also can contain another material that would impart an additional property important to mechanical strength and thus optimize factors that affect the threshold strength that include, but are not limited to, controlling grain growth, changing the coefficient of thermal contraction, and changing the elastic modulus.
12. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite; and in which one or more of the materials is an amorphous material, without long range atomic order.
13. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite; and in which the materials are not ceramics such as oxides, carbides, nitrides, and borides, but are materials chosen from a group of materials known as polymers, where one polymer would have a lower thermal contraction coefficient relative to the other polymer(s).
14. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by the differential strain induced by the differential thermal contraction coefficients of the different materials used to form the composite; and in which the materials are not either ceramics or polymers, but are at least two materials chosen from a

group of materials known as metals, where one metal would have a lower thermal contraction coefficient relative to the other metal(s).

15. A composite as in claims 1, 2, 3, or 4, in which the compressive stresses arise during cooling from a processing temperature to room temperature, caused by a volume expansion of one of the materials that undergoes a crystallographic phase transformation during cooling; and in which the material that exhibits a volume increase due to a structural phase transformation is zirconia with the tetragonal structure at high temperature, which transforms at a temperature below approximately 1100 °C to its monoclinic structure with a volume increase of approximately 3 %; and in which other materials including, but not limited to, alumina (Al_2O_3) and mullite ($2\text{SiO}_2 \cdot 3\text{Al}_2\text{O}_3$) can be used as the other material(s) in the composite, which would partially constrain the volume increase of the zirconia material and thus produce the desired compressive stresses in the transformed zirconia material.

16. A method of processing the composites as in claims 1, 2, 3, or 4, using powder of the materials which are heated to a temperature where the materials are made dense by sintering.

17. A method of processing the composite as in claims 1 or 2, comprising the following steps: each of the materials is first formed as powder sheets; the sheets are then alternately stacked together and pressed together into contact; and then the sheets are heated to a temperature that would cause the densification of the materials.

18. A method of processing the composite as in claims 1 or 3, comprising the following steps: one or more materials are first formed from a powder as cylindrical rods; the cylindrical rods are then coated with another material in which compressive stresses will arise during processing; the coated rods are pressed together to deform them into prismatic cylinders that are separated from each other by the coating material; and, after this pressing operation, the composite structure is then made dense by heating to a high temperature to induce sintering.

19. A method of processing the composite as in claims 1 or 4, comprising the following steps: one or more materials are first formed from a powder as spheres; the spheres are then coated with another material in which the compressive stresses will arise during processing; the coated spheres are then pressed together to deform them into polyhedra that are separated by the coating material; and the powder composite is then heated to a temperature where the powders densify to form a dense composite material.

20. A method of processing the composite as in claims 1 or 2, in which the materials are already dense materials that are stacked together and bonded together with an applied pressure.

21. A method of processing the composite as in claims 1, 3, or 4, in which the materials that do not contain the compressive stresses are separately made with the described shape and then bonded together with the material that will contain the compressive stress.

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